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Electrically Modulated Optical Properties of Fluorescent Chiral Nematic Liquid Crystals

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Due to the superior optical properties and tremendous application prospects in the field of optical devices, both rare earth complex (REC) and chiral nematic liquid crystal (CNLC) have attracted widespread attention in the fields of theoretical research and engineering applications. Among the research on the optical behaviors of CNLC or REC, the controllable modulation of selective reflection of CNLCs and emitted fluorescence of RECs is of great significance to fabricated tunable optical materials. In this study, europium (III) complexes are dissolved and assembled in the chiral matrix of CNLCs to form binary CNLC-REC composites due to excellent compatibility between RECs and CNLCs. The selective reflection combined with the photoluminescence of binary fluorescent CNLCs are investigated, an electrically-controlled microscopic structure model is established to elaborate the dual-mode optical modulation based on the stable CNLC-REC composites. The reflectance of CNLCs can be tuned in the process from planar state with brilliant Brrag reflection to focal conic state with chaotic scattering, the intensity of fluorescence emitted by RECs can be modulated due to the increased scattering of incident UV light on the surface of CNLC-REC composite films. Furthermore, the dual-mode optical modulation can be operated at low voltages and the response time is within 3 ms. This facile and ultrafast methodology can be used to develop state-of-the-art tunable optical devices in the fields of LC display, fluorescent display and optical sensors.

Keywords: Electrically modulation, Fluorescence, Selective reflection, Chiral nematic liquid crystal

Introduction

Fluorescent materials in the states of solids, solutions and colloids include rare earth (RE) compounds, quantum dots, semiconductors and dyes, which are defined as optical converters that can absorb certain types of photon energy level and reach an unstable transition state, then release certain energy in the form of photons to return to a stable state [1-5]. Among all kinds of photoluminescent materials, fluorescent dye and rare earth (RE) material are important categories as a result of their extensive presence and application. Compared with the all organic fluorescent dye, RE materials containing inorganic ions usually possess higher chemical stability. Due to the energy level transition of 4f electrons, rare earth ions (Sm^{3+}, Eu^{3+}, Tb^{3+} and Dy^{3+}) can emit light from ultraviolet region to infrared region. However, in consideration of the low stability, poor solubility, difficult processability and low luminous efficiency, isolated RE ionic compounds are commonly functionalized with organic ligands via coordination bonds to form rare earth complexes (RECs) and provide superior processability and enhanced fluorescence. The emission modes of RECs include photoluminescence, electroluminescence, triboluminescence, chemiluminescence and bioluminescence according to the excitation source [6-11], and RECs acting as an efficient luminescent center have drawn tremendous attention in the field of illumination, display, bioimaging and fluorescent probes [12-16]. In the field of theoretically research and engineering applications, the optical modulation of RECs is of meaningful challenge and great significance, which makes RECs tunable optical materials. In the field of color display, liquid crystal (LC) is a type soft optical material with self-assembled ordered structure, and the micro structures and macro properties are highly sensitive to temperature, electricity, light and stress [17-24]. LCs have been widely used to fabricate functional optical materials and manufacture display devices due to the Fredericks transition effect and electro-optic response mechanism. However, as the LC is not light emitting itself, and liquid crystal displays (LCDs) usually need other optical accessories (polarisers and color filters) which inevitably shield part of the light to realize its function, therefore, the transmitted intensity and reflected intensity of LCDs are not sufficiently high, which is a disadvantage in the field of LCDs.

In order to solve the disadvantage of low optical intensity (or low luminance) of LCDs, researchers has proposed a methodology of developing binary photonic composites possessing high luminance of fluorescent materials and tunable orientation order of LCs [25-32]. There are mainly two strategies for fabricating LC-REC conjugated materials, chemical bonding and physical coupling. The former one refers to the complexing reaction between RE ionics and LC ligands, Schiff's base, β-Enaminoketonates, β-diketonates are widely used as LC ligands to form bonded LC-REC materials [25-28], in this case, LCs are tightly bonded by metal ions, which makes the LC-REC materials very rigid and difficult to response to external stimulus. While the physically coupled LC-REC materials are generally realized by mixing and dissolving non-liquid crystalline RECs (guest) in a LC matrix (host), typically, only a small amount of REC doping (0.1wt% or less) could emit intensive fluorescence, the LC host can be thermotropic LCs or lyotropic LCs. Luminescent materials with narrow band photoluminescence and liquid-crystalline properties at room temperature can be obtained by doping the nematic liquid crystal (NLC) host matrices (MBBA or 5CB) with RECs [28]. REC also can embed into LC physical gels consisting of 5CB and amino acid-based gelators, the resulted composites can be switched between a nontransparent off-state and a transparent on-state, and produce intense red light when irradiated with UV-light [29]. Non-mesogenic RECs in anisotropic LCs can emit polarized luminescence due to the polarization effects of LC host [30]. Near-infrared photoluminescent LC-REC materials are

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